CLAIMS

1. A storage medium that contains instructions executable by a computer system to configure the computer system as a garbage collector that reclaims for reuse memory allocated by a mutator executing on the computer system, wherein the garbage collector performs a plurality of successive marking cycles, in each of which the garbage collector:

A) performs a marking operation in which the garbage collector traces reference chains from a root set and makes marks associated with respective objects thereby encountered;

B) thereafter performs a succession of collection space increments within the marking cycle;

C) repeatedly calculates a measure of the cumulative efficiency of collection that has taken place during the marking cycle and determines whether the cumulative efficiency thereby calculated satisfies a set of at least one marking-initiation criterion; and

D) if so, terminates that marking cycle and begins the next marking cycle.

2. A storage medium as defined in claim 1 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

3. A storage medium as defined in claim 2 wherein one said marking-initiation criterion is that at least a threshold number of collections have occurred during the marking cycle.

4. A storage medium as defined in claim 1 wherein the cumulative collection efficiency for a marking cycle is calculated as the ratio of an amount of memory reclaimed during that marking cycle to an amount of time taken to by collection during that marking cycle.

5. A storage medium as defined in claim 4 wherein, in determining the amount of memory reclaimed in a cycle, the garbage collector includes the memory reclaimed by all space-incremental-collection operations that take place after the end of that marking operation.

6. A storage medium as defined in claim 5 wherein:

A) the garbage collector treats the heap as divided into regions; and

B) the marking operation includes reclaiming regions in which all objects satisfy an unreachability criterion based on that marking operation's results.

7. A storage medium as defined in claim 6 wherein, in determining the amount of memory reclaimed in a cycle, the garbage collector includes the amount of memory reclaimed as part of the marking cycle's marking operation but omits any memory reclaimed by any space-incremental-collection operations that take place before the end of that marking operation.

8. A storage medium as defined in claim 4 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

9. A storage medium as defined in claim 1 wherein:

A) each of a plurality of the collection space increments reclaims a collection set within the heap; and

B) the garbage collector bases the collection set's selection on the marks made by one said marking operation's results.

10. A storage medium as defined in claim 9 wherein:

A) the garbage collector treats the heap as divided into regions, for which it maintains respective remembered sets that in the collection space increments it uses to determine whether objects in the collection set are referred

to from outside the collection set and are therefore potentially reachable; and

B) the garbage collector additionally bases the collection set's selection on the sizes of the remembered sets.

11. A storage medium as defined in claim 9 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

12. A storage medium as defined in claim 11 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

13. A storage medium as defined in claim 12 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

14. A storage medium as defined in claim 9 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

15. A storage medium as defined in claim 14 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

16. A storage medium as defined in claim 14 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

17. A storage medium as defined in claim 9 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

18. A storage medium as defined in claim 17 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

19. A storage medium as defined in claim 1 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

20. A storage medium as defined in claim 19 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

21. A storage medium as defined in claim 19 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

22. A storage medium as defined in claim 1 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

23. A storage medium as defined in claim 22 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

24. For reclaiming for reuse memory allocated by a mutator executing on the computer system, a method comprising employing the computer system to performs a plurality of successive marking cycles, each of which includes:

A) performing a marking operation by tracing reference chains from a root set and making marks associated with respective objects thereby encountered;

B) thereafter performing a succession of collection space increments within the marking cycle;

C) repeatedly calculating a measure of the cumulative efficiency of collection that has taken place during the marking cycle and determining whether the cumulative efficiency thereby calculated satisfies a set of at least one marking-initiation criterion; and

D) if so, terminating that marking cycle and beginning the next marking cycle.

25. A method as defined in claim 24 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

26. A method as defined in claim 25 wherein one said marking-initiation criterion is that at least a threshold number of collections have occurred during the marking cycle.

27. A method as defined in claim 24 wherein the cumulative collection efficiency for a marking cycle is calculated as the ratio of an amount of memory reclaimed during that marking cycle to an amount of time taken to by collection during that marking cycle.

28. A method as defined in claim 27 wherein, the memory reclaimed by all space-incremental-collection operations that take place after the end of that marking operation is included in determining the amount of memory reclaimed in a cycle.

29. A method as defined in claim 28 wherein:

A) the method includes treating the heap as divided into regions; and

B) the marking operation includes reclaiming regions in which all objects satisfy an unreachability criterion based on that marking operation's results.

30. A method as defined in claim 29 wherein, the amount of memory reclaimed as part of the marking cycle's marking operation is included in determining the amount of memory reclaimed in a cycle, but the amount of memory reclaimed by any space-incremental-collection operations that take place before the end of that marking operation is not.

31. A method as defined in claim 27 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

32. A method as defined in claim 24 wherein:

A) each of a plurality of the collection space increments reclaims a collection set within the heap; and

B) the collection set's selection is based on the marks made by one said marking operation's results.

33. A method as defined in claim 32 wherein the method includes:

A) treating the heap as divided into regions and maintaining therefor respective remembered sets that in the collection space increments are used to determine whether objects in the collection set are referred to from outside the collection set and are therefore potentially reachable; and

B) additionally basing the collection set's selection on the sizes of the remembered sets.

34. A method as defined in claim 32 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

35. A method as defined in claim 34 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

36. A method as defined in claim 35 wherein each of a plurality of the collection space increments includes determining whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuating potentially reachable objects from the collection set without evacuating any object thus identified, and reclaiming the collection set.

37. A method as defined in claim 32 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

38. A method as defined in claim 37 wherein each of a plurality of the collection space increments includes determining whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuating potentially reachable objects from the collection set without evacuating any object thus identified, and reclaiming the collection set.

39. A method as defined in claim 37 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

40. A method as defined in claim 32 wherein each of a plurality of the collection space increments includes determining whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuating potentially reachable objects from the collection set without evacuating any object thus identified, and reclaiming the collection set.

41. A method as defined in claim 40 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

42. A method as defined in claim 24 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

43. A method as defined in claim 42 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

44. A method as defined in claim 42 wherein each of a plurality of the collection space increments includes determining whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuating potentially reachable objects from the collection set without evacuating any object thus identified, and reclaiming the collection set.

45. A method as defined in claim 24 wherein each of a plurality of the collection space increments includes determining whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuating potentially reachable objects from the collection set without evacuating any object thus identified, and reclaiming the collection set.

46. A method as defined in claim 45 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

47. A computer system configured by stored instructions as a garbage collector that reclaims for reuse memory allocated by a mutator executing on the computer system, wherein the garbage collector performs a plurality of successive marking cycles, in each of which the garbage collector:

A) performs a marking operation in which the garbage collector traces reference chains from a root set and makes marks associated with respective objects thereby encountered;

B) thereafter performs a succession of collection space increments within the marking cycle;

C) repeatedly calculates a measure of the cumulative efficiency of collection that has taken place during the marking cycle and determines whether the cumulative efficiency thereby calculated satisfies a set of at least one marking-initiation criterion; and

D) if so, terminates that marking cycle and begins the next marking cycle.

48. A computer system as defined in claim 47 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

49. A computer system as defined in claim 48 wherein one said marking-initiation criterion is that at least a threshold number of collections have occurred during the marking cycle.

50. A computer system as defined in claim 47 wherein the cumulative collection efficiency for a marking cycle is calculated as the ratio of an amount of memory reclaimed during that marking cycle to an amount of time taken to by collection during that marking cycle.

51. A computer system as defined in claim 50 wherein, in determining the amount of memory reclaimed in a cycle, the garbage collector includes the memory reclaimed by all space-incremental-collection operations that take place after the end of that marking operation.

52. A computer system as defined in claim 51 wherein:

A) the garbage collector treats the heap as divided into regions; and

B) the marking operation includes reclaiming regions in which all objects satisfy an unreachability criterion based on that marking operation's results.

53. A computer system as defined in claim 52 wherein, in determining the amount of memory reclaimed in a cycle, the garbage collector includes the amount of memory re-

claimed as part of the marking cycle's marking operation but omits any memory reclaimed by any space-incremental-collection operations that take place before the end of that marking operation.

54. A computer system as defined in claim 50 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

55. A computer system as defined in claim 47 wherein:

A) each of a plurality of the collection space increments reclaims a collection set within the heap; and

B) the garbage collector bases the collection set's selection on the marks made by one said marking operation's results.

56. A computer system as defined in claim 55 wherein:

A) the garbage collector treats the heap as divided into regions, for which it maintains respective remembered sets that in the collection space increments it uses to determine whether objects in the collection set are referred to from outside the collection set and are therefore potentially reachable; and

B) the garbage collector additionally bases the collection set's selection on the sizes of the remembered sets.

57. A computer system as defined in claim 55 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

58. A computer system as defined in claim 57 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

59. A computer system as defined in claim 58 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an asso-

ciated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

60. A computer system as defined in claim 55 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

61. A computer system as defined in claim 60 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

62. A computer system as defined in claim 60 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

63. A computer system as defined in claim 55 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

64. A computer system as defined in claim 63 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

65. A computer system as defined in claim 47 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

66. A computer system as defined in claim 65 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

67. A computer system as defined in claim 65 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

68. A computer system as defined in claim 47 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

69. A computer system as defined in claim 68 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

70. An electromagnetic signal that represents instructions executable by a computer system to configure the computer system as a garbage collector that reclaims for reuse memory allocated by a mutator executing on the computer system, wherein the garbage collector performs a plurality of successive marking cycles, in each of which the garbage collector:

A) performs a marking operation in which the garbage collector traces reference chains from a root set and makes marks associated with respective objects thereby encountered;

B) thereafter performs a succession of collection space increments within the marking cycle;

C) repeatedly calculates a measure of the cumulative efficiency of collection that has taken place during the marking cycle and determines whether the cumulative efficiency thereby calculated satisfies a set of at least one marking-initiation criterion; and

D) if so, terminates that marking cycle and begins the next marking cycle.

71. An electromagnetic signal as defined in claim 70 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

72. An electromagnetic signal as defined in claim 71 wherein one said marking-initiation criterion is that at least a threshold number of collections have occurred during the marking cycle.

73. An electromagnetic signal as defined in claim 70 wherein the cumulative collection efficiency for a marking cycle is calculated as the ratio of an amount of memory reclaimed during that marking cycle to an amount of time taken to by collection during that marking cycle.

74. An electromagnetic signal as defined in claim 73 wherein, in determining the amount of memory reclaimed in a cycle, the garbage collector includes the memory reclaimed by all space-incremental-collection operations that take place after the end of that marking operation.

75. An electromagnetic signal as defined in claim 74 wherein:

A) the garbage collector treats the heap as divided into regions; and

B) the marking operation includes reclaiming regions in which all objects satisfy an unreachability criterion based on that marking operation's results.

76. An electromagnetic signal as defined in claim 75 wherein, in determining the amount of memory reclaimed in a cycle, the garbage collector includes the amount of memory reclaimed as part of the marking cycle's marking operation but omits any memory reclaimed by any space-incremental-collection operations that take place before the end of that marking operation.

77. An electromagnetic signal as defined in claim 73 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

78. An electromagnetic signal as defined in claim 70 wherein:

A) each of a plurality of the collection space increments reclaims a collection set within the heap; and

B) the garbage collector bases the collection set's selection on the marks made by one said marking operation's results.

79. An electromagnetic signal as defined in claim 78 wherein:

A) the garbage collector treats the heap as divided into regions, for which it maintains respective remembered sets that in the collection space increments it uses to determine whether objects in the collection set are referred to from outside the collection set and are therefore potentially reachable; and

B) the garbage collector additionally bases the collection set's selection on the sizes of the remembered sets.

80. An electromagnetic signal as defined in claim 78 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

81. An electromagnetic signal as defined in claim 80 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

82. An electromagnetic signal as defined in claim 81 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

83. An electromagnetic signal as defined in claim 78 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

84. An electromagnetic signal as defined in claim 83 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

85. An electromagnetic signal as defined in claim 83 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

86. An electromagnetic signal as defined in claim 78 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

87. An electromagnetic signal as defined in claim 86 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

88. An electromagnetic signal as defined in claim 70 wherein the marking operation occurs at least in part concurrently with the mutator's execution.

89. An electromagnetic signal as defined in claim 88 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

90. An electromagnetic signal as defined in claim 88 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the

marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

91. An electromagnetic signal as defined in claim 70 wherein in each of a plurality of the collection space increments the garbage collector determines whether objects in an associated collection set within the heap satisfy an unreachability criterion based on the marking operation's results, evacuates potentially reachable objects from the collection set without evacuating any object thus identified, and reclaims the collection set.

92. An electromagnetic signal as defined in claim 91 wherein one said marking-initiation criterion is that the cumulative efficiency has peaked.

93. A garbage collector for reclaiming for reuse memory allocated by a mutator executing on the computer system, the garbage collector including:

A) means for performing a marking operation by tracing reference chains from a root set and making marks associated with respective objects thereby encountered;

B) means for thereafter performing a succession of collection space increments within the marking cycle;

C) means for repeatedly calculating a measure of the cumulative efficiency of collection that has taken place during a marking cycle that begins with the marking operation and determining whether the cumulative efficiency thereby calculated satisfies a set of at least one marking-initiation criterion; and

D) means for, if so, terminating that marking cycle and beginning a subsequent marking cycle.